

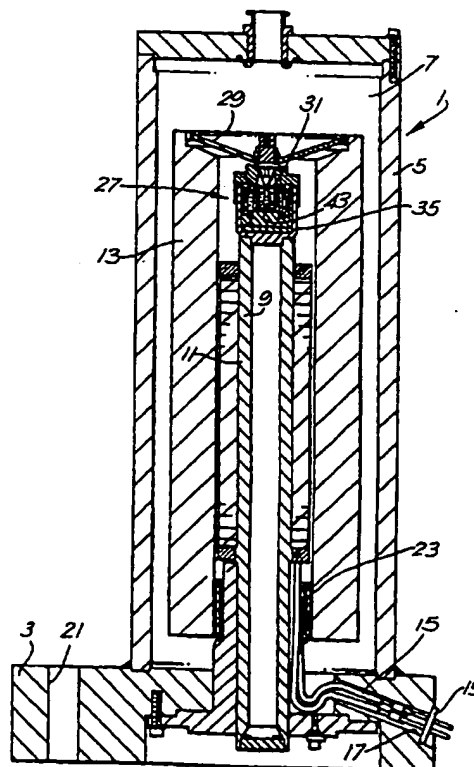
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Published*Without international search report and to be republished upon receipt of that report.***(54) Title:** AN ENERGY STORAGE AND CONVERSION APPARATUS**(57) Abstract**

An energy storage and conversion apparatus (1) comprising a containment (5) defining a vacuum chamber (7), a support shaft (9) within the vacuum chamber (7), a stator (11) on the shaft (9) and a cylindrical rotor (13) which, in use, is driven by the stator (11) to store energy as kinetic energy of the rotor (13) and acts with the stator (11) as a generator to release energy, wherein the rotor (13) is supported by the shaft (9) via an end cap (29) which, as the rotor (13) speed increases, deflects from a conical shape towards a planar shape. As a result, failure of the apparatus (1) does not occur when the rotor (13) expands due to centrifugal forces. Further, the position of the rotor (13) relative to the stator (11) and magnetic bearing on the shaft (9) is kept essentially constant, even if the length of the rotor (13) decreases due to Poisson effects.



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AN ENERGY STORAGE AND CONVERSION APPARATUS

This invention relates to energy storage and conversion apparatus, and in particular to an apparatus wherein a
5 cylindrical rotor is driven by a stator within the rotor to store energy as kinetic energy of the rotor and wherein energy can be withdrawn from the rotor when the stator and rotor act as a generator.

Energy storage and conversion apparatus of the
10 aforementioned type have already been described in some of the present applicant's earlier patent specifications. The applicant has, however, continued to develop its energy storage and conversion apparatus and, as a result thereof, has invented an apparatus as herein described.

15 According to a first aspect of the present invention, there is provided an energy storage and conversion apparatus comprising

a containment defining a vacuum chamber,
a support shaft within the vacuum chamber,
20 a stator on the shaft and
a cylindrical rotor which, in use, is driven by the stator to store energy as kinetic energy of the rotor and acts with the stator as a generator to release energy,
wherein the rotor is supported by the shaft via an end
25 cap which, as the rotor speed increases, deflects from a conical shape towards a planar shape.

When the rotor is rotated at high speed, such as between approximately 800 Hz and 1200 Hz, radial expansion of the rotor can occur. By providing an end cap which deflects in
30 the required manner, the end cap can continue to support the rotor and avoid failure of the apparatus, even at such high speeds.

Preferably the support shaft is substantially vertical and the end cap is mounted on the top of the support shaft
35 and engages the upper end of the cylindrical rotor.

Further, the end cap preferably engages the rotor with a friction fit. Some form of glue or resin may, however, be applied between the rotor and the end cap to ensure that the

rotor is held securely, if necessary.

Irrespective of whether a friction fit or a permanent bond is formed between the rotor and the end cap, the end cap is preferably strain matched to the rotor.

- 5 The end cap is preferably fitted such that it deflects downwardly as the rotor speed increases.

Further, as the speed of the rotor increases and the rotor expands radially, Poisson effects cause contraction of the rotor. This contraction of the rotor can affect the
10 interaction of the rotor with a magnetic or electromagnetic support bearing mounted on the lower end of the support shaft. Hence, an additional advantage provided by the deflecting end cap is that the rotor is effectively lowered slightly relative to the support shaft as the end cap
15 deflects, thereby keeping the rotor accurately aligned with the magnetic bearing on the support shaft. With this in mind, a typical figure for the amount of contraction of a carbon fibre rotor when rotating at the speeds given is in the region 3.5mm per rotor length of 1 meter.

- 20 In theory, the end cap could be fitted such that it deflects upward, but this would clearly not assist in retaining the rotor in position on the support shaft.

Although the end cap may, at rest, make an angle of between 5° and 40° with the horizontal, a preferred angle is
25 between 15° and 25°, more preferably about 20°. Such an angle avoids excess strain across the end cap and allows the end cap to deflect and lower the rotor, in use, by up to about 5mm or so, if the end cap has a thickness of about 7.5mm and a radius of about 130mm.

- 30 Preferably the end cap comprises layers of carbon fibre. Further, the end cap may comprise layers of glass fibre. If glass fibre is used in combination with carbon fibre, the layers of glass fibre preferably overlie the carbon fibre. In any event, the fibres in each layer are preferably
35 substantially uni-directional. As a result, the end cap has significant strength and reliability.

Although the end cap may be supported on the shaft by any appropriate means, a preferred means is a pin bearing

which acts between the end cap and the support shaft.

According to a second aspect of the present invention, there is provided a pin bearing comprising a pin carrying a pin head mounted in a cup within a first cavity and a second
5 cavity outside the first cavity, the second cavity communicating with the first cavity by a least one channel, wherein bearing oil within the cavities, during use, is circulated by rotation of the pin head in the cup between the two cavities to disperse heat generated between the pin
10 head and the cup.

If the bearing oil is not circulated away from the cup, the temperature of the oil may increase to several hundred degrees centigrade, which would have a significant effect on the viscosity of the oil and, indeed, the oil may even boil.
15 Clearly, if the viscosity of the oil varies significantly, the oil will not function satisfactorily.

In a preferred embodiment, a lip is provided on the pin for returning bearing oil driven up the pin from the first cavity to the second cavity. The lip may comprise a
20 frustoconical portion which tapers towards the cavities.

An oil guard preferably surrounds the lip to direct bearing oil into the second cavity. This guard may be formed as part of a cap which closes the two cavities.

The cup of the pin bearing is preferably carried by a
25 damping element which sits on guide struts attached to a housing of the pin bearing. Minor vibrations of the rotor may therefore be damped.

The damping element may include apertures through which the bearing oil circulates to and/or from the second cavity.

30 In a preferred embodiment, the pin head includes a spherical spiral groove which, during use, pumps the bearing oil.

As will be appreciated, an energy storage and conversion apparatus according to the first aspect of the present
35 invention may include a pin bearing according to the second aspect of the invention.

According to a third aspect of the present invention, there is provided a pin bearing for a rotor with load relief

start-up comprising a pin carrying a pin head received in a cup filled with bearing oil, means for biasing the cup towards the pin head and a ball bearing race acting to carry the pin and pin head until rotation of the pin head relative to the cup generates sufficient pressure in the bearing oil to provide a film of oil between the pin head and the cup to lift the rotor during use off the ball bearing race until the weight of the rotor is borne wholly by the pin and pin head acting on the cup.

10 Such a pin bearing prevents excessive wear occurring at low rotor speeds between the pin head and the cup, both of which are likely to be made of metal.

 Although any appropriate biasing means may be used, an helical spring providing light pressure to the cup is
15 perfectly acceptable.

 According to another embodiment of pin bearing according to the present invention which provides load relief start-up, there is provided a pin bearing comprising a pin carrying a pin head received in a cup, a passageway through
20 the cup to a position below the pin head and a pressurised oil feed which, during start-up of the bearing, lifts the pin head off the cup to reduce friction between the pin head and the cup.

 The pressurised oil feed may be deactivated during
25 normal running of the pin bearing.

 Load relief start-up may also be provided by means of a powerful axial electromagnet which can support the weight of the rotor during start-up. As the rotor approaches its operating speed, the electromagnet may be gradually phased
30 off.

 Specific embodiments of the present invention are now described, by way of example only, with reference to the accompanying drawings, in which:-

35 Figure 1 is a sectional side view of an energy storage and conversion apparatus according to the present invention;

 Figure 2 is an enlarged sectional side view of the pin bearing incorporated in the apparatus of Figure 1;

Figure 3 is a section on A-A of Figure 2; and

Figure 4 is a schematic side sectional view of a pin bearing with load relief start-up according to the present invention.

5

With reference to Figures 1-3 of the accompanying drawings, an energy storage and conversion apparatus 1 comprises a base member 3, a containment 5 mounted on the base member 3 defining a vacuum chamber 7, a substantially
10 vertical shaft 9 within the vacuum chamber 7, a stator 11 mounted on the shaft 9 and a cylindrical rotor 13 which, in use, is driven by the stator 11 to store energy as kinetic energy of the rotor 13 and acts with the stator 11 as a generator to release energy. Electrical contacts 15 for the
15 stator 11 pass through an opening 17 in the base member 3 which is closed via a vacuum seal 19.

Stator 11 is not shown in any detail in Figure 1, but may be of any appropriate type incorporating a core defining a plurality of poles, such as four poles, about which coils
20 are wound to produce magnetic flux which is directed by the pole faces towards magnetic material embedded in the rotor 13 to cause the rotor 13 to rotate. In this way, energy can be stored as kinetic energy of the rotor. Conversely, if energy is to be withdrawn from the apparatus 1, the rotor 13
25 and stator 11 can act as a generator to produce an electrical output via the power electronics (not shown) of the apparatus 1.

The base member 3 of the apparatus 1 has significant strength by virtue of its thickness and the material from
30 which it is made, which may be aluminium, for example. Holes 21, one of which is shown, through the base member 3 receive bolts (not shown) for securing the base member 3 to a floor or the like of considerable mass and strength. As a result, the energy storage and conversion apparatus 1 will
35 be held firmly in position, even if the apparatus 1 fails.

The rotor 13 is formed from fibre reinforced composite materials. For example, the rotor 13 may have an inner layer of E-glass and an outer layer of carbon fibre

composite. Any other suitable materials could, however, alternatively be used, provided that they provide the required properties for the rotor. In this regard, the inner layer of glass is relatively cheap and provides a reasonable amount of mass to the rotor 13. The E-glass is impregnated with magnetised material, in the form of particles or powder, between the fibres or tows of the glass fibre in the E-glass. The outer layer of the rotor 13 is included primarily to support the inner layer and is, therefore, formed of a material having significant strength when spinning at high speed, such as 800-1200 Hz. Carbon fibre composites are particularly suitable for this.

A magnetic bearing 23 is provided towards the lower end of the support shaft 9 under the stator 11. The magnet, which may be a permanent magnet or an electromagnet, interacts with the magnetic material embedded in rotor 13 to position the bottom end of the rotor 13 radially about the stator 11. In theory, the magnet 23 could be used to support some of the weight of the rotor 13, especially if the magnet 23 is an electromagnet. In such a scenario, the magnet would be controlling the axial position of the rotor 13 relative to the stator 11.

The rotor 13 is supported at its upper end by an end cap 29 via a friction fit. The end cap 29, when stationary, is essentially conical and tapers towards a pin bearing 27. The angle of inclination of the conical end cap 29 is in the region of 70-80° to the vertical. Hence, the end cap 29 is approximately 10-20° from being planar. These angles may, of course, vary, depending upon the particular application.

The end cap 29 is constructed by laying successive sheets of pre-shaped, pre-pregnated carbon fibre mats into a mold. The carbon fibres in each sheet are unidirectional, and each sheet is laid over the previous sheet at a predetermined angle until the required thickness of end cap is achieved. This ensures uniform strength over the entire section of the end cap. Although such an end cap performs its function quite adequately, there is a danger that fibres from the first and last layers running close to

the edge of the cap may break away during operation. Accordingly, to fix these vulnerable fibres in place and prevent breaking away, a final layer of glass fibre is applied to both faces of the end cap. This is achieved by
5 applying radial strips of uni-directional glass fibre mat to cover each entire surface. The glass fibre layer also performs a second function. In the carbon fibre construction of the end cap, the modulus of strain is low in the central mass of the cross-section, and at its highest
10 value on the outside edges. In practice the modulus of strain of the inner layers is about half the modulus of strain of the fibres in the outer layers. The strain modulus of glass fibre is approximately half the value of carbon fibre, therefore the modulus of strain of the glass
15 fibre layer on the outside faces of the end cap approximately match the modulus of strain in the centre portion of the end cap. This has the effect of equalising, or matching, the strain across the end cap cross-section.

The end cap 29 carries a pin 31 of the pin bearing 27.
20 The pin bearing 27 is threadedly received at the top of the support shaft 9, as shown in Figure 1. The pin bearing 27 is shown in detail in Figures 2 and 3 of the drawings.

With reference to Figure 2 of the drawings, the pin bearing 27 comprises a housing 33 which, as shown in Figure
25 1, is received in a case 35 threadedly attached to the top of the shaft 9. A non-rotating guard cap 37 closes the housing 33 and threadedly engages the case 35. A damping element 39, which carries a cup 41 into which the head 43 of the pin 31 is received, is housed within the housing 33.
30 The damping element 39 defines a first cavity 45 in which the cup 41 and pin head 43 are positioned. An annular flange 47 extends around the first cavity 45 and supports a downwardly extending skirt 49 which is received in an annular slot in the housing 33. The flange 47 also carries
35 three struts 51 which are all located at their bottom ends by an insert 53 which is fastened in the housing 33 by screws 55. The struts 51 prevent the damping element 39 from rotating, but allow radial motion relative to the

housing 33. The bearing oil 57 between the housing 33 and downwardly extending skirt 49 damps any such radial motion.

A second cavity 59 for bearing oil 57 is provided in the housing 33 outside the first cavity 45. Passageways 61,63 extend through a wall 65 of the housing 33 and a wall 67 of the damping element 39 respectively to allow fluid communication between the first cavity 45 and the second cavity 59. Further, a frustoconical lip 69 is provided on the shaft of the pin 31 and apertures 71 are provided in the flange 47 of the damping element 39.

During use, rotation of the rotor 13 causes rotation of the pin 31 and pin head 43 in the cup 41. The pin head 43 has a spherical spiral groove pattern 73 on its surface which pumps the bearing fluid 57 between the surface of the pin head 43 and the cup 41 to raise the pin head 43 away from the cup 41, thereby reducing the friction therebetween. The bearing fluid 57 tends to travel up the shaft of the pin 31 due to its rotational motion. On reaching the lip 69, the oil 57 is thrown outwardly by centrifugal forces and lands on the oil guard 37 adjacent thereto. The oil 57 subsequently runs down the guard 37 and drops back into the second cavity 59 via the apertures 71 in the flange 47. Hence, hot bearing oil 57 from the first cavity 45 is mixed with the much cooler bearing oil within the second cavity 59. Cooling of the bearing oil 57 thereby results.

As will be appreciated, the level of bearing oil 57 within the first and second cavities 45,59 is kept substantially the same by virtue of the communicating passageways 61,63 joining the two cavities. Hence, recirculation of the bearing oil 57 results.

Radial expansion of the rotor 13 occurs as rotor speed is increased, reaching maximum expansion at full operating speed. The end cap 29, which is initially conical, deflects towards a planar configuration. The deflection of the end cap 29 is designed to match the radial expansion of the rotor 13, thus maintaining the initial strain between the end cap 29 and rotor 13. Failure of the joint between the end cap 29 and the rotor 13 is thereby avoided. Further,

due to Poisson effects, as the rotor expands radially it contracts axially. The deflecting of the end cap 29 assists in negating this axial shortening because, as the end cap 29 deflects, the rotor 13 is effectively lowered. In this way, interaction between the magnet 23 and the rotor 13 is kept essentially constant. Problems associated with the set-up of the apparatus can, therefore, be avoided.

Turning now to Figure 4 of the drawings, another embodiment of pin bearing, this time with load relief start-up, is shown. Load relief during start-up is beneficial because significant wear can occur between a pin head and a cup before the pin bearing is running at a sufficient speed to generate an oil film between the bearing surfaces.

With reference to Figure 4, a housing 101 carries a cup 103 in which a pin head 105 of a pin 107 sits. The pin 107 is attached to an end cap (not shown). A downwardly extending tapered annular skirt 109 surrounds the pin 107. The pin bearing also includes an helical spring 111 applying a light upwards pressure on the cup 103 to urge the cup 103 towards the pin head 105. A ball bearing race 113 is also provided in the housing 101.

During start-up of the pin bearing, the weight of the rotor and end cap is borne by the skirt 109 engaged in the tapered inner race of ball bearing race 113. The cup 103 is lightly loaded against the pin head 105 by the pressure exerted by spring 111. As rotor speed increases, the bearing gradually generates pressure by virtue of the bearing oil (not shown) being pumped between the pin head 105 and the cup 103 due to the spherical spiral grooves on the pin head 105. The increasing pressure generates a film of oil between the pin head 105 and the cup 103, and further pressurises the oil chamber 117 under the cup by means of interconnecting passageway 120. The pressure in the oil chamber 117 is maintained by the bearing pumping action and the oil seal 118. As the oil pressure thus generated increases with speed, the cup 103 lifts, and with it, the rotor, until the cup 103 abuts with the disc 119. As this occurs, the skirt 109 disengages from the ball bearing race

113 and the weight of the rotor and end cap is borne entirely by the pin 107. Hence, the ball bearing race 113 carries the significant load of the end cap and rotor during initial start-up of the pin bearing. In this way, wear on the pin head 105 and cup 103 is reduced.

The ball bearing race 113 is supported on the disc 119 which encapsulates the cup 103, thereby retaining the cup 103 within the housing 101 even if the apparatus is turned upside down during transport, for example.

10 Another embodiment of pin bearing incorporating load relief start-up, which is not shown in the drawings, will now be described. In this embodiment, a passageway is formed through the cup to a position below the pin head of the pin bearing. A pressurised oil feed communicates with
15 the passageway so that, during start-up, pressurised oil is fed into the bearing cup directly under the pin head. If the pressure is sufficient, the pin head is separated from the cup almost immediately, thereby avoiding wear between the two component parts.

20 It will of course be understood that the present invention has been described above purely by way of example, and that modifications of detail can be made within the scope of the invention.

CLAIMS

1. An energy storage and conversion apparatus comprising
a containment defining a vacuum chamber,
5 a support shaft within the vacuum chamber,
a stator on the shaft and
a cylindrical rotor which, in use, is driven by the
stator to store energy as kinetic energy of the rotor and
acts with the stator as a generator to release energy,
10 wherein the rotor is supported by the shaft via an end
cap which, as the rotor speed increases, deflects from a
conical shape towards a planar shape.
2. An apparatus as claimed in claim 1, wherein the support
15 shaft is substantially vertical and the end cap is mounted
on the top of the support shaft and engages the upper end of
the cylindrical rotor.
3. An apparatus as claimed in claim 1 or claim 2, wherein
20 the end cap engages the rotor with a friction fit.
4. An apparatus as claimed in any preceding claim, wherein
the end cap is strain matched to the rotor.
- 25 5. An apparatus as claimed in any preceding claim, wherein
the end cap deflects downwardly as the rotor speed
increases.
6. An apparatus as claimed in any preceding claim, wherein
30 the end cap comprises layers of carbon fibre.
7. An apparatus as claimed in any preceding claim, wherein
the end cap comprises layers of glass fibre.
- 35 8. An apparatus as claimed in claim 7 when dependent upon
claim 6, wherein the layers of glass fibre overlie the
carbon fibre.

9. An apparatus as claimed in any one of claims 6 to 8, wherein the fibres in each layer are substantially uni-directional.
- 5 10. An apparatus as claimed in any preceding claim, wherein a pin bearing acts between the end cap and the support shaft.
- 10 11. An energy storage and conversion apparatus substantially as hereinbefore described with reference to and as shown in the accompanying drawings.
- 15 12. A pin bearing comprising a pin carrying a pin head mounted in a cup within a first cavity and a second cavity outside the first cavity, the second cavity communicating with the first cavity via a least one channel, wherein bearing oil within the cavities, during use, is circulated by rotation of the pin head in the cup between the two cavities to disperse heat generated between the pin head and
20 the cup.
- 25 13. A pin bearing as claimed in claim 12, wherein a lip is provided on the pin for returning bearing oil driven up the pin from the first cavity to the second cavity.
- 30 14. A pin bearing as claimed in claim 13, wherein the lip comprises a frustoconical portion which tapers towards the cavities.
- 15 15. A pin bearing as claimed in claim 13 or claim 14, wherein an oil guard surrounds the lip to direct bearing oil into the second cavity.
- 35 16. A pin bearing as claimed in any one of claims 12 to 15, wherein the cup is carried by a damping element which sits on guide struts attached to a housing of the pin bearing.
17. A pin bearing as claimed in claim 16, wherein the

damping element includes apertures through which the bearing oil circulates from the second cavity.

18. A pin bearing as claimed in any one of claims 12 to 17,
5 wherein the pin head includes a spherical spiral groove which, during use, pumps the bearing oil.
19. A pin bearing substantially as hereinbefore described with reference to and as shown in Figures 2 and 3 of the
10 accompanying drawings.
20. A pin bearing for a rotor with load relief start-up comprising
a pin carrying a pin head received in a cup filled with
15 bearing oil,
means for biasing the cup towards the pin head and
a ball bearing race acting to carry the pin and pin head until rotation of the pin head relative to the cup generates sufficient pressure in the bearing oil to provide
20 a film of oil between the pin head and the cup to lift the rotor during use off the ball bearing race until the weight of the rotor is borne wholly by the pin and pin head acting on the cup.
21. A pin bearing as claimed in claim 20, wherein the means
25 for biasing is an helical spring.
22. A pin bearing substantially as hereinbefore described with reference to and as shown in Figure 4 of the
30 accompanying drawings.
23. A pin bearing with load relief start-up comprising
a pin carrying a pin head received in a cup,
a passageway through the cup to a position below the
35 pin head and
a pressurised oil feed which, during start-up of the bearing, lifts the pin head off the cup to reduce friction between the pin head and the cup.

14

24. A pin bearing as claimed in claim 23, wherein the pressurised oil feed is deactivated during normal running of the pin bearing.

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25. A energy storage and conversion apparatus according to any one of claims 1 to 11 and including a pin bearing as claimed in any one of claims 12 to 24.

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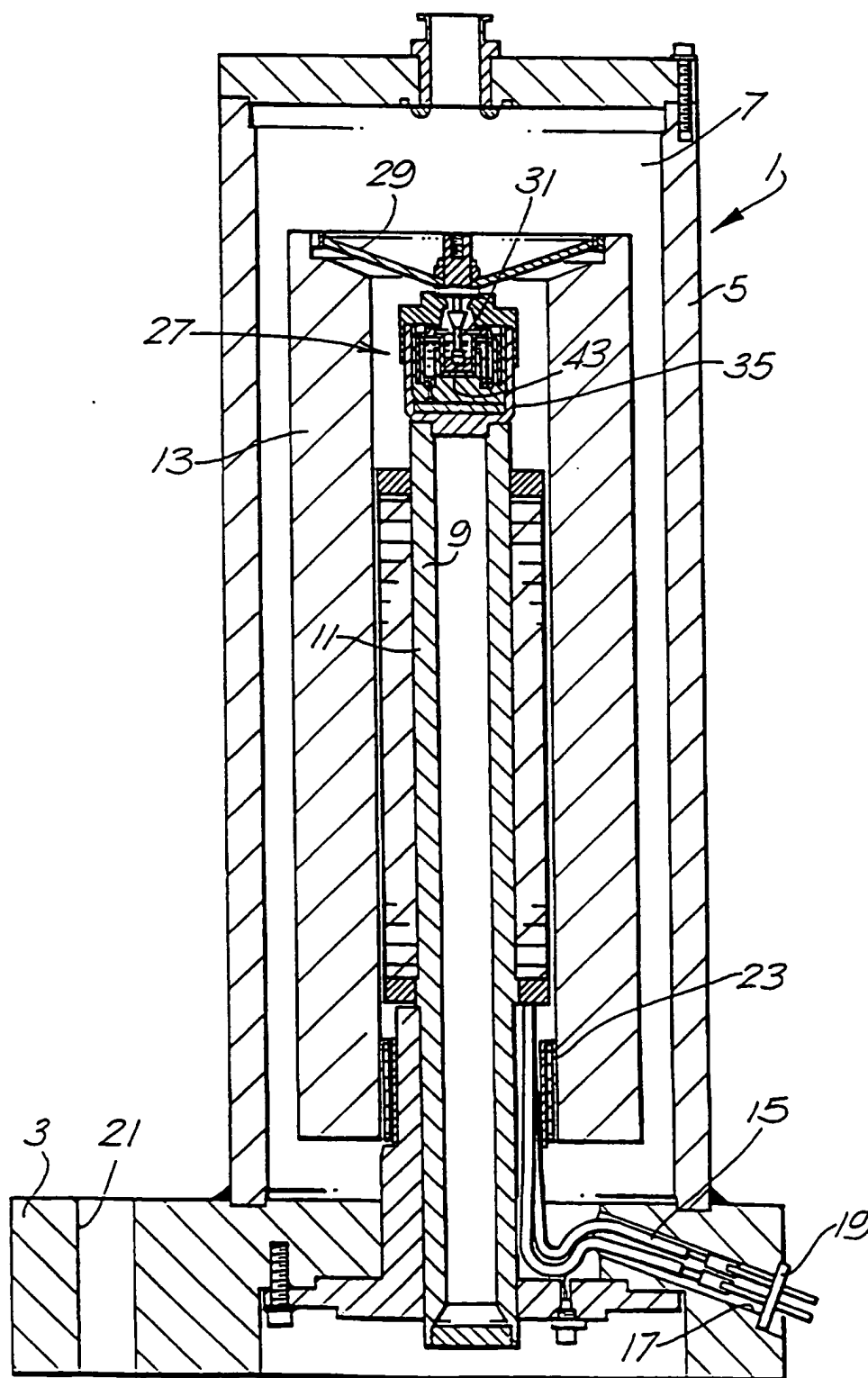


Fig. 1

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Fig. 2

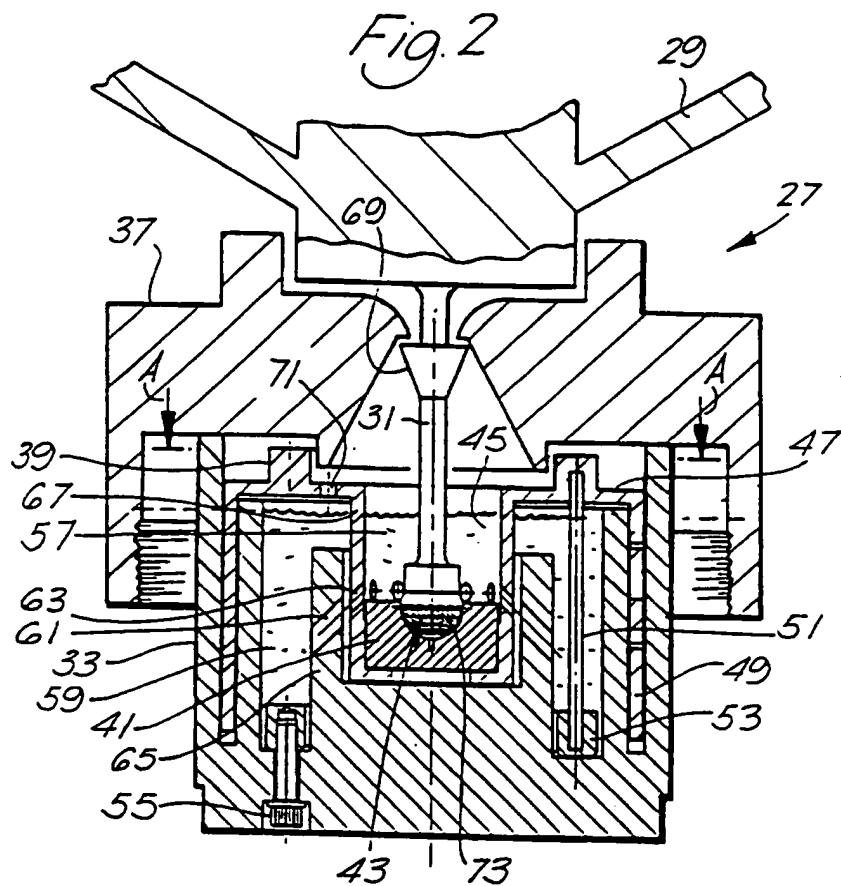


Fig. 3

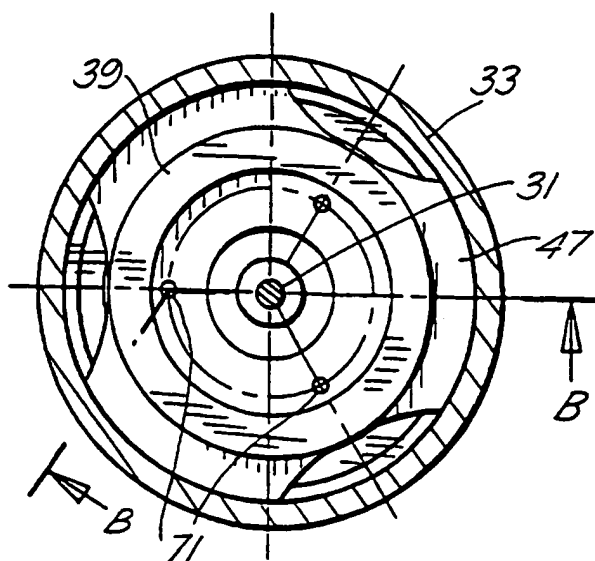
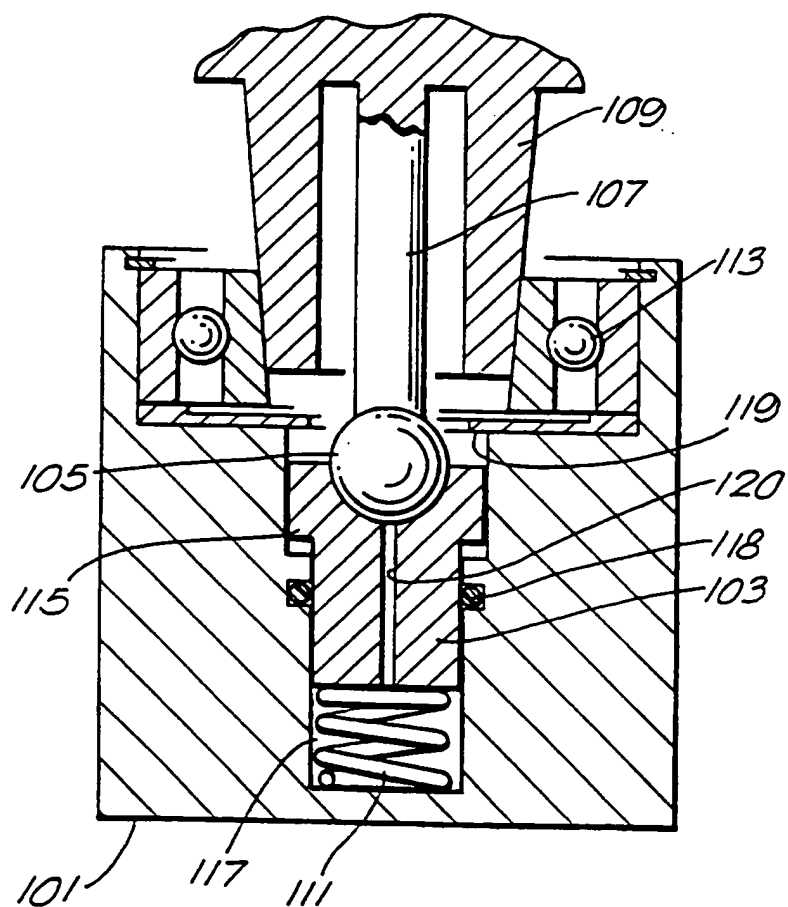


Fig. 4



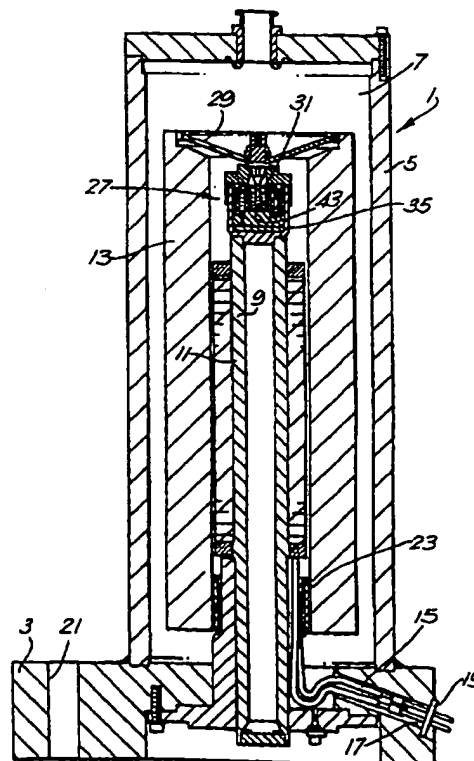


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(21) International Application Number: PCT/GB96/02410 (22) International Filing Date: 1 October 1996 (01.10.96) (30) Priority Data: 9520160.4 3 October 1995 (03.10.95) GB (71) Applicant (for all designated States except US): BRITISH NUCLEAR FUELS PLC [GB/GB]; Risley, Warrington, Cheshire WA3 6AS (GB). (72) Inventors; and (75) Inventors/Applicants (for US only): FULLWOOD, David, Tod [GB/GB]; International Energy Systems Limited, Chester High Road, Neston, South Wirral L64 3UE (GB). LLOYD, Nigel, Paul [GB/GB]; Urenco (Capenhurst) Limited, Capenhurst Works, Capenhurst, Chester CH1 6ER (GB). POLAK, Thomas, Alexander [GB/GB]; Neale Consulting Engineers Limited, 43 Downing Street, Farnham, Surrey GU9 7PH (GB). (74) Agent: JACKSON, Richard, Eric; Carpmals & Ransford, 43 Bloomsbury Square, London WC1A 2RA (GB).	(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, US, UZ, VN, ARIPO patent (KE, LS, MW, SD, SZ, UG), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG). Published <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i> (88) Date of publication of the international search report: 31 July 1997 (31.07.97)	

(54) Title: AN ENERGY STORAGE AND CONVERSION APPARATUS**(57) Abstract**

An energy storage and conversion apparatus (1) comprising a containment (5) defining a vacuum chamber (7), a support shaft (9) within the vacuum chamber (7), a stator (11) on the shaft (9) and a cylindrical rotor (13) which, in use, is driven by the stator (11) to store energy as kinetic energy of the rotor (13) and acts with the stator (11) as a generator to release energy, wherein the rotor (13) is supported by the shaft (9) via an end cap (29) which, as the rotor (13) speed increases, deflects from a conical shape towards a planar shape. As a result, failure of the apparatus (1) does not occur when the rotor (13) expands due to centrifugal forces. Further, the position of the rotor (13) relative to the stator (11) and magnetic bearing on the shaft (9) is kept essentially constant, even if the length of the rotor (13) decreases due to Poisson effects.



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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 96/02410

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 H02K7/02 F16F15/315 F16F15/30 F16C27/08 F16C33/10
F16C17/20 F16C21/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 H02K F16F F16C B04B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO 93 24765 A (RISOE FORSKNINGSCENTER ;WAAGEPETERSEN GASTON BIRGER FO (DK)) 9 December 1993 see page 1, line 17 - line 21 see page 2, line 1 - line 15 see page 3, line 20 - line 22 see abstract; figure 1 ---	1-4,6-11
Y	US 5 065 060 A (TAKAHASHI ISAO ET AL) 12 November 1991 see column 1, line 1 - column 2, line 68 see abstract; figure 1 ---	1-4,6-11
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

25 April 1997

Date of mailing of the international search report

18.06.97

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 96/02410

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP 0 145 182 A (BRITISH PETROLEUM CO PLC) 19 June 1985 see page 2, line 10 - line 15 see page 2, line 30 - page 3, line 9 see page 3, line 16 - line 29 see page 8, line 14 - line 22 see abstract; figure 5 ---	1-11
A	US 4 223 240 A (THEYSE FREDERIK H) 16 September 1980 see abstract; figures 1,4 see column 4, line 66 - column 5, line 27 ---	1,12-19
P,A	GB 2 293 281 A (BRITISH NUCLEAR FUELS PLC) 20 March 1996 see the whole document ---	1-11
X	DE 27 25 002 A (ULTRA CENTRIFUGE NEDERLAND NV) 15 December 1977 see page 6, paragraph 4 see page 8, paragraph 2 ---	12,13,16
Y		19
A	see page 8, line 30 - page 9, line 3 see page 13, line 5 - line 9 ---	14,15, 17,18, 20-25
Y	GB 2 202 302 A (LAING JOHN SERVICES) 21 September 1988 see page 5, line 20 - page 6, line 9 see abstract; figure 1 ---	20-22
X	PATENT ABSTRACTS OF JAPAN vol. 007, no. 237 (M-250), 21 October 1983 & JP 58 124822 A (TOKYO SHIBAURA DENKI KK), 25 July 1983, ---	23-25
Y		19-22
A	see abstract ---	12,18
A	FR 2 120 401 A (COMMISARIAT A L'ENERGIE ATOMIQUE) 18 August 1972 see page 3, line 22 - line 40 see page 5, line 1 - line 24 see claims 1-11; figures 1-3 -----	12

INTERNATIONAL SEARCH REPORT

International application No.

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Box I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. CLAIMS : 1-11
2. CLAIMS : 12-25

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1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
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Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

information on patent family members

Int. onal Application No

PCT/GB 96/02410

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 9324765 A	09-12-93	AU 4308493 A DE 69307315 D DE 69307315 T EP 0642635 A JP 7507129 T US 5562014 A	30-12-93 20-02-97 24-04-97 15-03-95 03-08-95 08-10-96
US 5065060 A	12-11-91	JP 2036740 A	06-02-90
EP 0145182 A	19-06-85	AU 562426 B AU 3450484 A CA 1230992 A DE 3471509 A DK 160637 B JP 60109641 A US 4821599 A	11-06-87 21-11-85 05-01-88 30-06-88 15-06-85 18-04-89
US 4223240 A	16-09-80	NL 7514748 A	21-06-77
GB 2293281 A	20-03-96	AU 3183795 A CA 2196417 A WO 9605646 A NO 970549 A	07-03-96 22-02-96 22-02-96 06-02-97
DE 2725002 A	15-12-77	NL 7605918 A AU 505167 B AU 2562477 A BR 7703622 A GB 1559461 A JP 1154955 C JP 52146810 A JP 57045135 B	06-12-77 08-11-79 07-12-78 21-03-78 16-01-80 15-07-83 06-12-77 25-09-82
GB 2202302 A	21-09-88	GB 2172687 A GB 2202301 A,B	24-09-86 21-09-88
FR 2120401 A	18-08-72	DE 2165686 A NL 7118214 A	10-08-72 04-07-72